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SUMMARY PILOT WATERSHED REPORT
FELTON-HERRON CREEK, MILL CREEK, MICHIGAN

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16. Abstract (Limit: 200 words)

This document summarizes the findings from studies of two small Michigan sub-watersheds; Felton-Herron Creek, a sub-watershed which was utilized to investigate land drainage from a liquid waste disposal area and Mill Creek which was representative of a large fruit growing area.

Land application (spray irrigation) of secondary effluent to old fields with various management practices, cultivated row crops and hardwood forest in the Felton-Herron watershed was monitored. Particular emphasis was placed on nitrate and total phosphorus. Proper selection of vegetation, irrigation rate and harvest management minimized nitrogen and phosphorus discharges. Sugar maple forests are inefficient for removing nitrogen from watewater.

Mill Creek was monitored particularly for 57 pesticides and suspended solids to determine pesticide input from tributaries and changes in pesticides content as the creek changes from agricultural to urban land use. With this information scientists evaluated the pesticide and sediment mass leaving the watershed. Though suspended sediment leaving the watershed is not a serious problem considered alone, transport of pesticides is closely tied with sediment movement. Measures to control sediment should control chlorinated hydrocarbons movement.

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FELTON-HERRON CREEK, MILL CREEK

PILOT WATERSHED STUDIES

SUMMARY PILOT WATERSHED REPORT

Submitted to

International Joint Commission

Reference Group on Pollution from Land Use Activities

Task C Technical Committee - Synthesis
and Extrapolation Work Group

by

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January 31, 1978

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3.0 DISCLAIMER

The findings and views expressed in this report are those of the project investigators and do not necessarily reflect the views of the International Joint Commission. This report is intended to be a working document for the sole purpose of developing synthesized reports among members of PLUARG, the Core Group and SEWG. Data presented in this report were developed using loading calculations which represented the best available methodology available within the time constraints of the study. At the recent suggestion of the IJC statisticians, these calculations are being redone using different techniques. Thus all tabular data presented here are subject to change at a later date on completion of the calculations.

This study was carried out as part of the program of the Pollution from Land Use Activities Reference Group of the International Joint Commission.

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8.0 SUMMARY

Two land uses, (1) fruit orchard farming and (2) municipal wastewater irrigation, are being studied to assess the sources, forms and amount of pollutants that may be transported from these areas to the boundary waters of the Great Lakes. Of primary concern in the fruit orchard areas is the movement of pesticides and in the wastewater irrigation areas the movement of nutrients. A mass balance approach is being attempted in both study areas using intensive sampling methodologies in order to directly measure the major mass flows of critical materials from the land to surface stream channels. Continuous records of stream discharge at selected sites coupled with an adaptive automated water sampling scheme are being used as the methodological basis for determining the mass flows of some 57 pesticide parameters and 26 other paramters of water quality.

Wastewater irrigation sites, if properly designed and managed, do not appear to represent a significant source of non-point pollutants. Mismanagement or poor design on such systems can present serious problems to both the quality of surface and ground water. The output of this phase of the study will be design and management recommendations (remedial measures) aimed at developing optimal solutions to the problems of both surface and ground water quality.

Fruit orchard farming employs intensive use of many pesticides. We are finding detectable amounts of pesticide chemicals being transported from the land to the water. The significance of this has not as yet been resolved but will be addressed in our final report.

9.0 INTRODUCTION

Two Michigan subwatersheds are included as representative U.S. watersheds for land drainage studies on the input of polluting materials to the Great Lakes. One, Felton-Herron Creek, is a sub-watershed of the Grand River with features well suited for investigating land drainage from a liquid waste disposal area. The other, Mill Creek, represents a basin typical of the large fruit growing area of southwestern lower Michigan.

9.1 STUDY QUESTIONS

The general purpose of the pilot watershed studies being conducted in the State of Michigan is to evaluate land drainage from agricultural or other land uses not adequately represented in the other U.S. Watershed Studies. The two selected for inclusion will significantly extend the resolution of the impact of unique land uses to streams tributary to the Great Lakes.

9.1.1 FELTON-HERRON CREEK

Recent laws have mandated consideration of land application systems as an alternative to more conventional waste treatment facilities. Land irrigation for treatment of municipal wastewaters occurs on only a small percentage of land area in the Great Lakes Region. In Michigan, for example, 40 small communities ranging in size from 100 to 6,600 persons are presently utilizing some form of land irrigation. These 40 small communities serve a combined population of over 59,000 people. In addition, the Muskegon system serves a total population of over 79,000 people. Thus, land treatment of municipal effluent is already used for close to 140,000 people in Michigan alone, and this technology is expanding as other small communities adopt it. While land treatment of wastewaters has been shown to effectively lower nutrient concentrations to levels comparable to or lower than those achieved by conventional waste treatment facilities, the impact of diffusing these point sources to non-point sources and the impact of various vegetation management schemes on these non-point discharges through field tiles, seepages, runoff, or groundwater recharge has not been well documented. In studies at Michigan State University, the impacts of various irrigation and vegetative management schemes on discharge of phosphorus and nitrogen to streams and groundwater in the Great Lakes Region have been investigated. These studies form the core of the Felton-Herron Creek "Watershed" study.

The general objectives of the Felton-Herron Creek portion of the study are to (1) develop management and design criteria to minimize surface and subsurface water contamination in wastewater irrigation systems, and (2) arrive at reasonable pollutant loading values associated with these practices.

9.1.2 MILL CREEK

The objective of this research effort is to assess the magnitude of the pesticides and sediment transported from a watershed typical of the kind of agriculture subject to the most intensive pesticide usage in the Great Lakes Basin; fruit orchard farming.

The pesticide transport process can be divided into two categories: (1) pesticide transported in solution, and (2) pesticide adsorbed to particulate matter and convected along with the sediment load of the stream. This distinction is necessary if one is to accurately identify the source of the problem.

The removal and subsequent transport of agricultural non-point source pollutants are directly related to the rainfall-runoff process. Overland flow is responsible for the initial movement of pollutants from the land surface to the stream. Once in the stream, the pollutant may be transported considerable distances by the stream flow. In the particular case of pesticides the quantity transported is related to the solubility and adsorptive characteristics of the pesticide considered. The translocation of pesticides that are adsorbed to or coated on sediment particles depends on the many variables influencing the capability of a stream to transport sediment, whereas those that are water soluble will be conveyed in amounts that are directly proportional to their concentration level and the stream discharge.

In view of the above description of the processes responsible for the transport of pesticides, the major objective of our research effort is to determine the relative amount of pesticide transported on the suspended solids and in solution. As a result of such a determination it would then be possible to ascertain the magnitude and source of this non-point source problem.

9.2 STUDY APPROACH

This study was conducted entirely within the Grand River, Michigan watershed. Main stem monitoring of the Grand River was not an aspect of this program, but rather two discrete sub-basins within the Grand River watershed were selected to examine specialized land uses. Results from the two sub-basins (Mill Creek and Felton Drain) are to be treated separately.

There will be no attempt for closure on mass balances for the Grand River watershed as a unit since only two of many land uses were examined. The general approach on the Mill Creek and Felton studies was to gather data on an intensive scale from small areas in order to characterize transport mechanisms between the land and water.

9.3 METHODS

9.3.1 FELTON-HERRON CREEK

The conceptual basis for our monitoring approach for this watershed is shaped by the fact that there are two types of hydrological events experienced in the watershed. The first is natural precipitation (rain and snow) and the second is the terrestrial irrigation of secondary effluent. Our monitoring network thus consists of: (1) stations located on the primary site and (2) stations located to intercept surface flows before entry into the Felton channel. Monitoring stations on the main channel yield integrated data on all upstream inputs regardless of source and "side stations" yield direct estimates of the output from a particular land use. Through upstream-downstream comparisons of water quantity and quality, through temporal differences in water quantity and quality initiated by natural precipitation or by irrigation and by direct calculation of "side station" inputs we have the capability for good closure on our mass balance estimates.

The Felton watershed can be subdivided into three general land uses which are subjected to wastewater irrigation: (1) old fields with various management practices; (2) cultivated row crops, and (3) hardwood forest. Wastewater can be applied as secondary effluent, as renovated secondary effluent (polished via series flow through shallow man-made lakes) or various intermediate qualities.

Surface flows at all stations are guaged and automatic samplers are triggered by a rising hydrograph. All water analyses are done in the laboratory according to acceptable and established procedures. Soil sampling, vegetative sampling, subsurface water quality, and atmospheric inputs are being measured to complete the mass balances. Emphasis is being placed on the parameters of nitrogen and phosphorus due to their relative importance to subsurface and surface water quality, respectively.

9.3.1.1 Old Field Irrigation Studies

For the past several years efforts have been directed toward the determination and understanding of hydrologic and nutrient mass balances on a three hectare subwatershed subjected to year-round spray of municipal sewage effluent, as part of the Felton-Herron Creek Watershed project. Spray operations have continued into the spring of this year with extensive monitoring of water and key nutrient movements, resulting in an assessment of the overall mass balances. In particular, winter spray operations were emphasized, the objective being to determine the feasibility of wastewater spray irrigation under the duress of a northern winter climate. Runoff from such systems, especially during spring runoff, could constitute a major non-point pollution source if not properly managed. Such systems are increasingly being adopted on a wide scale basis and appropriate operating criteria need to be developed.

Automatic recording equipment was winterized and used to monitor runoff and collect samples for subsequent nutrient analysis. Suction lysimeters

were installed throughout the site for nutrient sampling. The key nutrients monitored were nitrogen, phosphorus and chloride. Subsequently, water and nutrient mass balances were made on a seasonal basis.

9.3.1.2 Hardwood Forest Irrigation Studies

Secondary municipal effluent from East Lansing, Michigan, was spray irrigated on a mature beech-sugar maple forest during the 1976 growing season. One 1.2 ha plot received 5 cm/wk, another 10 cm/wk, and a third acted as a non-irrigated control. The sampling regime was similar to that for the old field studies.

9.3.1.3 Vegetation Harvest Studies

The purpose of this study is to evaluate the relationship of timing of wastewater irrigation and of vegetation harvest on the leaching of nitrogen and phosphorus.

Experimental plots on a deep well drained soil were instrumented to measure nutrient concentrations in water leaving the site through tile drains or deep percolation. Vegetative treatments included the following: legumes, predominantly alfalfa, harvested 3 to 4 times annually; forage grasses harvested 3 times annually; grasses mowed bi-weekly; grasses unharvested; annual forages-corn, sorghum, sorghum-sudan hybrids harvested once annually; volunteer old field vegetation unharvested, harvested once annually or harvested twice annually. All treated plots were irrigated weekly during the growing season with secondary municipal sewage effluent at rates varying between 2.5 and 10 cm per week.

9.3.2 MILL CREEK

Mill Creek is located in mid-western lower Michigan. It originates in Cranberry Lake and flows southwesterly through Kent County, joining the Grand River at Comstock Park. Three tributaries enter the creek. Upstream, the land is rolling with orchards and grain predominating. Proceeding downstream the creek goes from agricultural to urban development. In general the stream may be described as a cold water, usually clear creek, with a drainage system representative of a mid-western agricultural and urban creek of moderate size and low reflief gradient.

Nine permanent sampling stations were established from Cranberry Lake to the creek's mouth as it enters the Grand River. The stations were primarily selected to determine pesticide input from its tributaries and to determine any changes in pesticide content as the creek goes from agricultural to urban development. Of the nine stations, three are equipped with automatic water samplers triggered by a rising hydrograph. These stations are also equipped with stage recorders. Precipitation gauges are maintained at three stations. Water quality analyses include suspended sediment and 57 pesticide paramters.

Previous measurements of water quality had indicated that the majority of the pesticide and sediment movement along Mill Creek occurs during

storm runoff events. As a result, water samples are taken only during storm runoff periods. Twenty-eight samples are taken per runoff event with each sample reflecting the average concentration over some predetermined time interval. The water samples are then analyzed for pesticide (adsorbed and dissolved) and sediment concentrations. In conjunction with the water quality data, simultaneous measurements of stream discharge are also made. Hence, by coupling the stream flow and the water quality measurements the mass of pesticide and sediment leaving the watershed can be evaluated.

9.4 KEY PARAMETERS

9.4.1 FELTON-HERRON CREEK

Although a broad spectrum of inorganic chemicals were monitored, emphasis was placed on total phosphorus and nitrate.

9.4.2 MILL CREEK

Many pesticide residues were examined. Data would suggest that those of importance include DDT, DDE, Atrazine and Guthion. Nutrient parameters were not emphasized.

10.0/11.0 TABULATED RESULTS AND CONCLUSIONS

10.1/11.1 LAND USES AND PRACTICES

The Felton-Herron Creek Studies represent specialized land uses not included in the 10 agreed upon general categories. Wastewater irrigation on row crops, old fields and forests identify the general uses and practices. Detailed information on soils, sub-basin areas, vegetation and management will be presented in the final report subdivided into the following categories:

1. Old Field Studies
2. Cropland Studies
3. Forest Studies
4. Felton Drain Studies
5. Baseline Watershed Studies
6. Winter Irrigation Studies

10.2/11.2 LOADS

All loads for our sampling stations are calculated using the Beale ratio estimator technique which was incorporated into our existing programs which uses flow-weighted mean concentration and mean discharge per pre-set time interval. We use the following strata: (1) annual loading; (2) seasonal loading [(a) spring runoff as determined from discharge records, (b) spring post-runoff, (c) summer, (d) fall, (e) winter]. In every case, load estimates were generated using the unbiased flow-weighted mean concentration and mean daily flow for the period using the Beale technique.

10.2.1/11.2.1 OLD FIELD STUDIES

The old field vegetation sites effectively controlled discharge of N and P to ground and surface waters. While mineral N concentration in the top soil (15 cm depth) exceeded 10 mg/l at the end of the growing season, further plant soil interaction to the 120 cm depth lowered that concentration to levels much lower than the 10 mg N/l drinking water standard throughout the April through October wastewater irrigation season. When irrigated at 5 cm/wk, N discharges from the old field were less than 30 kg N/ha (Table 1). Doubling that irrigation rate quadrupled the discharge of N when the begetation was unharvested (Table 2).

Management of the vegetation by one or two harvests per year lowered the discharge of N to groundwater for the 10 cm/wk rate. At the 5 cm/wk rate the primary affect was to change the fate of the added N. For the unharvested plots most of the added N was retained in the soil-vegetation system; for the harvested plots most was removed in the vegetation harvest.

Table 1 : Mass Balance for Inorganic N for the 5 cm/week Old Field Irrigation Site. Values in kg N/ha.

	Input			No Harvest		One Harvest			Two Harvests		
Month	Precipi-tation	Irrigation	Total	Recharge	Retention	Vegetation Removal	Recharge	Retention	Vegetation Removal	Recharge	Retention
October 76	1.52	25.97	27.49	7.02	20.47	0	6.12	21.37	0	2.03	25.46
November 76	0.59	0	0.59	0.94	-0.35	0	0.67	-0.08	0	0.83	-0.25
December 76	0.38	0	0.38	0.54	-0.16	0	0.39	-0.01	0	0.43	-0.05
January 77	0.28	0	0.28	0.35	-0.07	0	0.26	0.02	0	0.25	0.03
February 77	4.65	0	4.65	0.50	4.15	0	0.38	4.27	0	0.31	4.34
March 77	2.05	0	2.05	1.35	0.70	0	1.11	0.94	0	0.59	1.46
April 77	3.00	10.13	13.13	3.32	9.81	0	2.91	10.22	0	0.65	12.48
May 77	0.36	17.94	18.30	0.98	17.32	0	1.75	16.55	0	0.66	17.64
June 77	3.01	15.42	18.43	0.30	18.13	145	1.54	-128.11	93	0.31	-74.88
July 77	1.29	25.79	27.08	1.00	26.08	0	2.91	24.17	0	1.08	26.00
August 77	1.77	26.26	28.03	1.44	26.59	0	5.47	22.56	0	1.51	26.53
September 77	3.35	21.51	24.86	11.10	13.76	0	6.68	18.18	88	1.52	-64.66
ANNUAL	22.25	143.02	165.27	28.84	136.43	145	30.19	-9.92	181	10.17	-25.90
Percent of Input	13	87	100	17	83	88	18	-6	110	6	16

Table 2 : Mass Balance for Inorganic N for the 10 cm/week Old Field Irrigation Site. Values in kg N/ha.

	Input			No Harvest		One Harvest			Two Harvests		
	Precipitation	Irrigation	Total	Recharge	Retention	Vegetation Removal	Recharge	Retention	Vegetation Removal	Recharge	Retention
October 76	1.52	49.69	51.21	35.7	15.51	0	15.2	36.01	0	24.4	26.81
November 76	0.59	0	0.59	1.6	-1.01	0	1.2	-0.61	0	1.2	-0.61
December 76	0.38	0	0.38	1.0	-0.62	0	0.7	-0.32	0	0.7	-0.32
January 77	0.28	0	0.28	0.7	-0.42	0	0.5	-0.22	0	0.4	-0.12
February 77	4.65	0	4.65	1.0	3.65	0	0.7	3.95	0	0.5	4.15
March 77	2.05	0	2.05	3.2	-1.15	0	2.2	-0.15	0	0.8	1.25
April 77	3.00	17.99	20.99	14.0	6.99	0	9.8	11.19	0	3.8	17.19
May 77	0.36	33.33	33.69	9.1	24.59	0	4.2	29.49	0	2.9	30.79
June 77	3.01	26.19	29.20	2.3	26.90	192	2.3	-165.10	145	2.0	-117.80
July 77	1.29	51.49	52.78	7.3	45.48	0	6.4	46.38	0	7.7	45.08
August 77	1.77	44.62	46.39	10.8	35.59	0	8.6	37.79	0	12.1	34.29
September 77	3.55	39.81	43.36	32.5	10.86	0	24.0	19.36	131	30.6	-118.24
ANNUAL	22.25	263.12	285.57	119.2	166.37	192	75.8	17.9	276	87.1	-77.5
Percent of Input	8	92	100	42	58	67	26	7	97	31	-27

Phosphorus concentrations remained at background (non-irrigation) levels. At these concentrations the discharge would be directly proportional to groundwater recharge volumes. Harvest of vegetation could be expected to extend the time before phosphorus discharges increase, however this period of study was too short to evaluate this effect.

When managed with 5 to 10 cm/wk with wastewater and harvested at least annually, old fields provided effective treatment of the wastewater and minimized discharges of N and P.

Runoff of N, P, and several other constituents of wastewater has been calculated on both a seasonal and annual basis using the Beale ratio estimator technique (Tables 3-7). No stratification beyond season was used. These data will be recalculated using event versus non-event strata and within event stratification for the final report. Present data (Tables 3-7) will probably not change drastically, although error limits will be reduced. Thus, data in these tables can be used as first approximations of loadings from wastewater irrigated old fields. Very little runoff occurred from unirrigated adjacent old field sites during post-spring runoff and summer seasons (the irrigation period). Thus, loadings from these seasons can be contributed almost completely to losses from the 3.6 ha wastewater irrigation site (average irrigation rate was 7.5 cm/week). On this basis, stream loadings of total P from this spray site was about 1.1 kg/ha/yr; loadings from an adjacent spray site used for year-round irrigation at 5 cm/wek was 2 kg/ha/yr. Loadings of total P from wastewater irrigated old fields would appear to be on the order of 1-2 kg/ha/yr from sandy loam soils in Michigan. Loadings of inorganic N were about 4 kg/ha/yr and organic N were about 2.5 kg/ha/yr for a total N loading of 6.5 kg/ha/yr.

10.2.2/11.2.2 CROPLAND STUDIES

Nitrogen concentrations in soil waters of both the root zone and the subsoil varied widely during the growing season. Type of crop and its management affected this variation. The tall growing cool season grasses commonly used in pastures and grass hay of the Great Lakes Region effectively maintained N concentrations well below the 10 ppm limit for NO_3-N in drinking water. Discharges of N in the groundwater recharge during the May through April irrigation season averaged 9 to 15 kg N/ha even at the 7.5 cm/wk irrigation rate (Table 8). The harvest schedule had little effect on the concentration of mineral N in the recharge. The bi-weekly mowing and the no-cutting management were about as effective as the three harvest management when irrigated at the 7.5 cm/wk rate. Legumes were somewhat less effective than grasses in preventing discharge of N. From 18 kg N/ha at the 2.5 cm/wk rate to 85 kg N/ha at the 7.5 cm/wk rate leached from the site. Peak discharges occurred briefly following each harvest of the legumes. Summer annuals contributed the greatest N losses, averaging 34 to 150 kg N/ha during the irrigation season. At the 5.0 and 7.5 cm/wk rates most of the discharge appeared during the first 7 weeks after planting. This suggested that an alternative management, splitting the yearly rate - 2.5 cm/wk for the first 6-8 weeks and 7.5 cm/wk for the next 8 weeks, would minimize N losses.

TABLE 3 : DATA SUMMARY FOR STREAM EXPORT OF MOLYBDATE REACTIVE PHOSPHORUS AND TOTAL PHOSPHORUS FOR THE OLD FIELD SPRAY SITE.

	MOLYBDATE REACTIVE PHOSPHORUS				TOTAL PHOSPHORUS			
	Weighted Mean (mg/l)	Total Load (kg/ yr or season)	Unit Area Load (kg/ha/yr or season)*	% of Annual Load**	Weighted Mean (mg/l)	Total Load (kg/ yr or season)	Unit Area Load (kg/ha/yr or season)*	% of Annual Load**
Summer, 76 (137 days)	0.466	1.423 ± .252	0.126	---	0.541	1.650 ± .265	0.146	---
1976-77 WATER YEAR	0.290	1.372 ± .556	0.121	* *	0.884	4.184 ± 1.699	0.370	* *
Fall, 76 (62 days)	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Winter, 76-77 (68 days)	N.F.	N.F.	N.F.	0	N.F.	N.F.	N.F.	0
Spring Runoff, 77 (48 days)	0.290	0.490 ± .073	0.043	35.54	0.737	1.246 ± .355	0.110	29.73
Spring Post Runoff, 77 (50 days)	N.D.	N.D.	N.D.	N.D.	0.551	0.324 ± .154	0.029	7.84
Summer, 77 (137 days)	N.D.	N.D.	N.D.	N.D.	1.188	2.389 ± 1.227	0.211	57.03

N.F. = No flow during this period.

N.D. = No data collected.

* = Total area drained = 11.32 ha; Area irrigated = 3.6 ha; Unit area load calculated using total area drained; Most irrigation occurred during spring post runoff and summer periods.

** = Percent of annual load calculated by dividing by separately run water year data.

TABLE 4: DATA SUMMARY FOR STREAM EXPORT OF NITRATE AND AMMONIA NITROGEN FOR THE OLD FIELD SPRAY SITE.

	NITRATE-NITROGEN				AMMONIA-NITROGEN			
	Weighted Mean (mg/l)	Total Load (kg/yr or season)	Unit Area Load (kg/ha/yr or season)*	% of Annual Load**	Weighted Mean (mg/l)	Total Load (kg/yr or season)	Unit Area Load (kg/ha/yr or season)*	% of Annual Load**
Summer, 76 (137 days)	2.030	6.192 ± 1.011	0.547	---	0.157	0.480 ± .209	0.042	---
1976-77 WATER YEAR	3.114	14.742 ± 5.580	1.303	**	0.183	0.866 ± .617	0.077	**
Fall, 76 (62 days)	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Winter, 76-77 (68 days)	N.F.	N.F.	N.F.	0	N.F.	N.F.	N.F.	0
Spring Runoff, 77 (48 days)	1.429	2.417 ± .177	0.214	16.42	0.070	0.118 ± .029	0.010	12.99
Spring Post Runoff, 77 (50 days)	1.703	1.000 ± .313	0.088	6.75	0.428	0.251 ± .137	0.022	28.57
Summer, 77 (137 days)	3.884	7.813 ± 4.224	0.690	52.95	0.187	0.376 ± .445	0.033	42.86

N.F. = No flow during this period.

N.D. = No data collected.

* = Total area drained = 11.32 ha; Area irrigated = 3.6 ha; Unit area load calculated using total area drained; most irrigation occurred during spring post runoff and summer periods.

** = Percent of annual load calculated by dividing by separately run water year data.

TABLE 5: DATA SUMMARY FOR STREAM EXPORT OF NITRITE AND KJELDAHL NITROGEN FOR THE OLD FIELD SPAY SITE.

	NITRITE-NITROGEN				KJELDAHL-NITROGEN			
	Weighted Mean (mg/l)	Total Load (kg/yr or season)	Unit Area Load (kg/ha/yr or season)*	% of Annual Load**	Weighted Mean (mg/l)	Total Load (kg/yr or season)	Unit Area Load (kg/ha/yr or season)*	% of Annual Load**
Summer, 76 (137 days)	0.257	0.784 ± .196	0.069	---	1.288	3.929 ± .361	0.347	---
1976-77 WATER YEAR	0.077	0.362 ± .154	0.032	* *	2.065	9.776 ± 2.535	0.864	* *
Fall, 76 (62 days)	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Winter, 76-77 (68 days)	N.F.	N.F.	N.F.	0	N.F.	N.F.	N.F.	0
Spring Runoff, 77 (48 days)	0.030	0.050 ± .006	0.004	12.50	1.735	2.934 ± .386	0.259	29.98
Spring Post Runoff, 77 (50 days)	0.066	0.039 ± .012	0.003	9.38	1.900	1.116 ± .385	0.099	11.46
Summer, 77 (137 days)	0.094	0.190 ± .100	0.017	53.13	2.385	4.797 ± 2.695	0.424	49.07

N.F. = No flow during this period.

N.D. = No data collected.

* = Total area drained = 11.32 ha; Area irrigated = 3.6 ha; Unit area load calculated using total area drained; Most irrigation occurred during spring post runoff and summer periods.

** = Percent of annual load calculated by dividing by separately run water year data.

TABLE 6: DATA SUMMARY FOR STREAM EXPORT OF CHLORIDE AND SUSPENDED SOLIDS FOR THE OLD FIELD SPRAY SITE.

	CHLORIDE				SUSPENDED SOLIDS			
	Weighted Mean (mg/l)	Total Load (kg/ yr or season)	Unit Area Load (kg/ha/yr or season)*	% of Annual Load**	Weighted Mean (mg/l)	Total Load (kg/ yr or season)	Unit Area Load (kg/ha/yr or season)*	% of Annual Load**
Summer, 76 (137 days)	125.778	383.68 ± 7.15	33.906	---	14.438	44.04 ± 11.58	1.276	---
1976-77 WATER YEAR	89.343	422.90 ± 103.3	37.372	* *	24.553	116.22 ± 140.51	10.270	* *
Fall, 76 (62 days)	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Winter, 76-77 (68 days)	N.F.	N.F.	N.F.	0	N.F.	N.F.	N.F.	0
Spring Runoff, 77 (48 days)	24.074	40.72 ± 4.92	3.598	9.63	24.553	41.525 ± 18.48	3.670	---
Spring Post Runoff, 77 (50 days)	104.450	61.34 ± 12.99	5.421	14.51	N.D.	N.D.	N.D.	N.D.
Summer, 77 (137 days)	109.690	220.62 ± 34.55	19.496	52.17	N.D.	N.D.	N.D.	N.D.

N.F. = No flow during this period.

N.D. = No data collected.

* = Total area drained = 11.32 ha; Area irrigated = 3.6 ha; Unit area load calculated using total drained; Most irrigation occurred during spring post runoff and summer periods.

** = Percent of annual load calculated by dividing by separately run water year data.

TABLE 7 : DATA SUMMARY FOR STREAM EXPORT OF SODIUM AND CALCIUM FOR THE OLD FIELD SPRAY SITE.

	SODIUM				CALCIUM			
	Weighted Mean (mg/l)	Total Load (kg/yr or season)	Unit Area Load (kg/ha/yr or season)*	% of Annual Load**	Weighted Mean (mg/l)	Total Load (kg/yr or season)	Unit Area Load (kg/ha/yr or season)*	% of Annual Load**
Summer, 76 (137 days)	79.168	241.50 ± 11.15	21.341	---	79.20	241.61 ± 12.79	21.351	---
1976-77 WATER YEAR	14.041	66.46 ± 44.11	5.873	**	24.814	117.46 ± 110.49	10.380	**
Fall, 76 (62 days)	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Winter, 76-77 (68 days)	N.F.	N.F.	N.F.	0	N.F.	N.F.	N.F.	0
Spring Runoff, 77 (48 days)	14.041	23.75 ± 5.80	2.099	35.74	24.814	41.97 ± 14.53	3.709	35.73
Spring Post Runoff, 77 (50 days)	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Summer, 77 (137 days)	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.

N.F. = No flow during this period.

N.D. = No data collected.

* = Total area drained = 11.32 ha; Area irrigated = 3.6 ha; Unit area load calculated using total area drained; Most irrigation occurred during spring post runoff and summer periods.

** = Percent of annual load calculated by dividing by separately run water year data.

Table 8: Mass Additions and Discharges of Inorganic N to the Cropland Sites During the Growing Season. Values in kg N/ha.

Irrigation Rate (cm/wk)	Crop Type	1976			1977			Total	
		Inputs			Inputs				
		Wastewater	Precipitation	Recharge	Wastewater	Precipitation	Recharge	Inputs	Recharge
2.5	Annuals	116	10	48	90	11	19	227	67
2.5	Legumes	116	10	24	90	11	11	227	35
2.5	Grasses	116	10	13	90	11	5	227	18
5.0	Annuals	184	10	89	186	11	90	391	179
5.0	Legumes	184	10	45	186	11	43	391	88
5.0	Grasses	184	10	14	186	11	8	391	22
7.5	Annuals	271	10	148	275	11	160	567	308
7.5	Legumes	271	10	98	275	11	68	567	166
7.5	Grasses	271	10	25	275	11	5	567	30

Croplands were generally effective in treating the wastewater. Related studies will show that the treatment resulted in lowered yields of all crops examined compared to what could be obtained by optimal crop management. Recognition should be made that the dual role of crop production and wastewater treatment results in a compromise in both treatment and production. With proper crop selection and management, the compromise is minimized.

10.2.3/11.2.3 FOREST STUDIES

Wastewater irrigation of two beech-sugar maple sites at rates of 5 and 10 cm/week demonstrate that forests are not ideal sites for spray irrigation of wastewater. On the 5 cm/week site, concentrations of inorganic N at the 150 cm depth were very close to concentrations in applied wastewater. On a mass balance basis (Table 9), retention of inorganic N by this forest was between 15 and 47% depending on whether this site is a contributing area to runoff or not. In either case, retention (wastewater renovation) was not adequate and this type of management should not be adopted because of potential groundwater NO_3-N contamination problems. Phosphorus retention by this site was excellent (Table 10). Thus, low N wastewater from lagoons could be applied to such forests with no problem.

The 10 cm/week forested spray irrigation was deliberately overloaded with wastewater. The water logging of this site apparently resulted in substantial increases in denitrification; therefore, this site was about 78% efficient at inorganic N removal (Table 11). However, this N removal efficiency was accomplished at the expense of increased runoff from this site. This increased runoff resulted in high inorganic N stream loadings of 32-47 kg/ha/yr (Table 11) and in high total P loadings of 14.5 to 22 kg/ha/yr (Table 12). Overall loading from this 2.4 ha forested site plus 16 ha of mixed forest and old fields are presented in Tables 13-17. Almost all of this loading was derived from the spray site according to Thornthwaite type water budget calculations for the area.

10.2.4/11.2.4 FELTON DRAIN STUDIES

Inputs to Felton Drain upstream of the wastewater irrigation site and outputs downstream of the site were monitored to ascertain the overall effect of this spray irrigation project on stream loading. These data (Tables 18-27) are not very conclusive for three reasons. First, input loadings are high and very variable because of a poultry production/research facility just upstream of the site. Manure from this operation is applied to the grassy area around the barns resulting in high inputs to Felton Drain. Secondly, the total area presently being irrigated is only a small fraction of the spray irrigation area drained by the output station (less than 15% of the total area). Third, the output of the lake system of the WQMP was diverted down Felton Drain in August, 1976. This lake output completely masked other inputs to the Drain. Thus, the 1975-76 data should be used for overall loadings and discreet land use studies already described above should be emphasized for best estimates of loadings from spray irrigation.

Table 9: Mass Balance for Inorganic Nitrogen (NO_3 + NO_2 + NH_4-N) for the 5 cm/week Forest Irrigation Site. Values in kg/ha.

Month	Precipitation*	Wastewater Irrigation	Total Input	Runoff**	Recharge**	Retention**	Recharge*** Only (No Runoff)	Retention***
October 76	1.52	26.80	28.32	2.98	16.49	8.85	29.94	-1.62
November 76	0.59	0	0.59	0.78	0	-0.19	2.45	-1.86
December 76	0.38	0	0.38	0	1.55	-1.17	1.55	-1.17
January 77	0.28	0	0.28	0	1.12	-0.84	1.12	-0.84
February 77	4.65	0	4.65	0.002	1.75	2.90	1.85	2.80
March 77	2.05	0	2.05	0.35	0.44	1.26	5.22	-3.17
April 77	3.00	11.28	14.28	2.11	9.57	2.60	19.58	-5.30
May 77	0.36	18.79	19.15	1.50	5.39	12.26	10.93	8.22
June 77	3.01	21.70	24.71	1.91	11.48	11.32	18.40	6.31
July 77	1.29	33.20	34.49	1.43	8.21	24.85	15.12	19.37
August 77	1.77	30.47	32.24	1.48	13.58	17.18	21.49	10.75
September 77	3.35	25.19	28.54	3.26	15.06	10.22	34.19	-5.65
ANNUAL	22.25	167.43	189.68	15.80	84.64	89.24	161.84	27.84
Percent of Input	11.73	88.27	100.00	8.33	44.62	47.05	85.32	14.68

* = Based on mean literature values for Michigan.

** = Runoff from spray site apportioned on basis of water available for recharge or runoff on basis of water budget calculations.

*** = All runoff from spray site assigned to 10 cm/wk area.

Table 10: Mass Balance Budget for Total Phosphorus for the 5 cm/week Forest Irrigation Site. Values in kg/ha.

Month	Precipitation*	Wastewater Irrigation	Total Input	Runoff**	Recharge**	Retention**	Recharge*** Only (No Runoff)	Retention***
October 76	0.014	6.308	6.322	1.311	0.083	4.929	0.151	6.171
November 76	0.006	0	0.006	0.345	0	-0.339	0.009	-0.003
December 76	0.004	0	0.004	0	0.003	0.001	0.003	0.001
January 77	0.003	0	0.003	0	0.003	0	0.003	0
February 77	0.004	0	0.004	0.001	0.008	-0.005	0.008	-0.004
March 77	0.019	0	0.019	0.114	0.002	-0.097	0.018	0.001
April 77	0.028	3.821	3.849	0.803	0.037	4.689	0.076	3.773
May 77	0.003	5.919	5.922	0.596	0.033	5.293	0.066	5.856
June 77	0.028	5.924	5.952	0.780	0.157	5.015	0.252	5.700
July 77	0.012	9.146	9.158	0.757	0.088	8.313	0.162	8.996
August 77	0.016	6.652	6.668	0.779	0.140	5.749	0.222	6.446
September 77	0.031	5.984	6.015	1.719	0.242	4.054	0.549	5.466
ANNUAL	0.168	43.754	43.922	7.205	0.796	35.922	1.519	42.403
Percent of Input	0.38	99.62	100	16.40	1.81	81.79	3.46	96.54

* = Based on Literature Value of 0.027 mg P/l for Michigan.

** = Runoff from spray site apportioned on basis of water available for recharge or runoff on basis of water budget calculations.

*** = All runoff from spray site assigned to 10 cm/week area.

Table 11 : Mass Balance for Inorganic Nitrogen (NO_3 + NO_2 + NH_4-N) for the 10 cm/week Forest Irrigation Site. Values in kg/ha.

Month	Precipitation*	Spray	Total Input	Runoff**	Recharge**	Retention**	Runoff***	Recharge***	Retention***
October 76	1.52	47.43	48.95	5.61	7.40	35.94	8.62	4.19	36.14
November 76	0.59	0	0.59	0.78	0	-0.19	1.56	0	-0.97
December 76	0.38	0	0.38	0	0.42	-0.04	0	0.42	-0.04
January 77	0.28	0	0.28	0	0.26	0.02	0	0.26	0.02
February 77	4.65	0	4.65	0.002	0.35	4.30	0.004	0.35	4.30
March 77	2.05	0	2.05	0.35	0.17	1.53	0.70	0	1.35
April 77	3.00	20.48	23.48	3.54	5.79	14.15	5.65	2.19	15.64
May 77	0.36	34.96	35.32	4.11	6.73	24.48	5.61	4.12	25.59
June 77	3.01	42.69	45.70	3.87	8.25	33.58	5.78	5.80	34.12
July 77	1.29	56.20	57.49	3.79	3.51	50.19	5.22	2.39	49.88
August 77	1.77	53.73	55.50	3.37	3.31	48.82	4.85	2.47	48.18
September 77	3.35	46.88	50.23	6.13	2.15	41.95	9.39	0.70	40.14
ANNUAL	22.25	302.37	324.62	31.55	38.34	254.73	47.38	22.89	254.35
Percent of Input	6.85	93.15	100.00	9.72	11.81	78.47	14.60	7.05	78.35

* = Based on mean literature values for Michigan.

** = Runoff from spray site apportioned on basis of water available for recharge or runoff from water budget calculations.

*** = All runoff from spray site assigned to 10 cm/week area.

Table 12: Mass Balance for Total Phosphorus for the 10 cm/week Forest Irrigation Site. Values in kg/ha.

Month	Precipitation*	Wastewater Irrigation	Total Inputs	Runoff**	Recharge**	Retention**	Runoff***	Recharge***	Retention**
October 76	0.014	11.717	11.731	2.476	0.060	9.195	3.787	0.034	7.910
November 76	0.006	0	0.006	0.345	0	-0.339	0.690	0	-0.684
December 76	0.004	0	0.004	0	0.008	-0.004	0	0.008	-0.004
January 77	0.003	0	0.003	0	0.005	-0.002	0	0.005	-0.002
February 77	0.004	0	0.004	0.001	0.007	-0.004	0.001	0.007	-0.004
March 77	0.019	0	0.019	0.114	0.002	-0.097	0.228	0	-0.209
April 77	0.028	7.604	7.632	1.351	0.070	6.211	2.154	0.025	5.453
May 77	0.003	11.883	11.886	1.630	0.124	10.132	2.226	0.076	9.584
June 77	0.028	11.904	11.932	1.579	0.240	10.113	2.359	0.169	9.404
July 77	0.012	18.263	18.275	1.997	0.214	16.064	2.754	0.146	15.375
August 77	0.016	13.305	13.321	1.776	0.164	11.381	2.555	0.122	10.644
September 77	0.031	11.928	11.959	3.231	0.159	8.569	4.950	0.051	6.958
ANNUAL	0.168	86.604	86.772	14.500	1.053	71.219	21.704	0.643	64.425
Percent of Input	0.19	99.81	100	16.71	1.21	82.08	25.01	0.74	74.25

* = Based on Literature Value of 0.027 mg P/l for Michigan.

** = Runoff from spray site apportioned on basis of water available for recharge or runoff on basis of water budget calculations.

*** = All runoff from spray site assigned to 10 cm/week area.

TABLE 2: DATA SUMMARY FOR STREAM EXPORT OF MOLYBDATE REACTIVE PHOSPHORUS AND TOTAL PHOSPHORUS FOR THE FORESTED SPRAY SITE.

	MOLYBDATE REACTIVE PHOSPHROUS				TOTAL PHOSPHORUS			
	Weighted Mean (mg/l)	Total Load (kg/ yr or season)	Unit Area Load (kg/ha/yr or season)*	% of Annual Load**	Weighted Mean (mg/l)	Total Load (kg/ yr or season)	Unit Area Load (kg/ha/yr or season)*	% of Annual Load**
1976-77 WATER YEAR	0.806	23.745 ± 4.655	1.294	* *	0.897	26.449 ± 4.435	1.442	* *
Fall, 76 (62 days)	1.231	1.494 ± 1.034	0.081	---	1.475	1.790 ± 1.673	0.098	6.85
Winter, 76-77 (77 days)	N.F.	N.F.	N.F.	---	N.F.	N.F.	N.F.	0
Spring Runoff, 77 (41 days)	0.148	0.619 ± .091	0.034	---	0.195	0.814 ± .118	0.044	3.11
Spring Post Runoff, 77 (48 days)	0.423	2.731 ± .033	0.149	---	0.846	5.462 ± .884	0.298	20.89
Summer, 77 (137 days)	N.D.	N.D.	N.D.	N.D.	1.041	18.075 ± 2.494	0.985	69.14

N.F. = No flow during this period.

N.D. = No data collected.

* = Total area drained = 18.35 ha; Area irrigated = 2.4 ha; Unit area load calculated using total area drained; Most irrigation occurred in spring post runoff and summer periods.

** = Percent of annual load calculated by adding seasonal values and dividing, not by separately calculated water year data.

TABLE 14: DATA SUMMARY FOR STREAM EXPORT OF NITRATE AND AMMONIA-NITROGEN FOR THE FORESTED SPRAY SITE.

	NITRATE-NITROGEN				AMMONIA-NITROGEN			
	Weighted Mean (mg/l)	Total Load (kg/yr or season)	Unit Area Load (kg/ha/yr or season)*	% of Annual Load**	Weighted Mean (mg/l)	Total Load (kg/yr or season)	Unit Area Load (kg/ha/yr or season)*	% of Annual Load**
1976-77 WATER YEAR	1.902	56.067 ± 7.770	3.056	* *	0.148	4.360 ± .897	0.238	* *
Fall, 76 (62 days)	3.185	3.865 ± 4.873	0.211	8.35	0.067	0.081 ± .187	0.004	1.31
Winter, 76-77 (77 days)	N.F.	N.F.	N.F.	0	N.F.	N.F.	N.F.	0
Spring Runoff, 77 (41 days)	0.479	1.999 ± .797	0.109	4.31	0.044	0.182 ± .025	0.010	3.28
Spring Post Runoff, 77 (48 days)	1.584	10.231 ± 1.327	0.558	22.08	0.446	2.884 ± .497	0.157	51.48
Summer, 77 (137 days)	1.742	30.256 ± 3.024	1.649	65.26	0.141	2.457 ± .387	0.134	43.93

N.F. = No flow during this period.

* = Total area drained = 18.35 ha; Area irrigated = 2.4 ha; Unit area load calculated using total area drained; Most irrigation occured in spring post runoff and summer periods.

** = Percent of annual load calculated by adding seasonal values and dividing, not by separately calculated water year data.

TABLE 15 : DATA SUMMARY FOR STREAM EXPORT OF NITRITE AND KJELDAHL-NITROGEN FOR THE FORESTED SPRAY SITE.

	NITRITE-NITROGEN				KJELDAHL-NITROGEN			
	Weighted Mean (mg/l)	Total Load (kg/yr or season)	Unit Area Load (kg/ha/yr or season)*	% of Annual Load**	Weighted Mean (mg/l)	Total Load (kg/yr or season)	Unit Area Load (kg/ha/yr or season)*	% of Annual Load**
1976-77 WATER YEAR	0.088	2.595 ± .345	0.141	* *	1.500	44.20 ± 10.80	2.409	* *
Fall, 76 (62 days)	0.101	0.123 ± .170	0.007	4.79	0.958	1.16 ± .40	0.063	1.59
Winter, 76-77 (77 days)	N.F.	N.F.	N.F.	0	N.F.	N.F.	N.F.	0
Spring Runoff, 77 (41 days)	0.043	0.181 ± .031	0.010	7.05	0.801	3.343 ± .135	0.182	4.57
Spring Post Runoff, 77 (48 days)	0.103	0.665 ± .106	0.036	25.89	3.221	20.81 ± 6.52	1.134	28.47
Summer, 77 (137 days)	0.092	1.600 ± .201	0.087	62.28	2.752	47.79 ± 4.94	2.605	65.37

N.F. = No flow during this period.

* = Total area drained = 18.35 ha; Area irrigated = 2.4 ha; Unit area load calculated using total area drained; Most irrigation occurred in spring post runoff and summer periods.

** = Percent of annual load calculated by adding seasonal values and dividing, not by separately calculated water year data.

TABLE 16: DATA SUMMARY FOR STREAM EXPORT OF CHLORIDE AND SUSPENDED SOLIDS FOR THE FORESTED SPRAY SITE.

	CHLORIDE				SUSPENDED SOLIDS			
	Weighted Mean (mg/l)	Total Load (kg/ yr or season)	Unit Area Load (kg/ha/yr or season)*	% of Annual Load**	Weighted Mean (mg/l)	Total Load (kg/ yr or season)	Unit Area Load (kg/ha/yr or season)*	% of Annual Load**
1976-77 WATER YEAR	98.885	2914.4 ± 117.3	158.849	* *	14.201	418.5 ± 127.8	22.810	* *
Fall, 76 (62 days)	109.577	133.0 ± 18.0	7.249	4.49	13.629	16.54 ± 24.00	0.902	---
Winter, 76-77 (77 days)	N.F.	N.F.	N.F.	0	N.F.	N.F.	N.F.	---
Spring Runoff, 77 (41 days)	51.328	214.2 ± 14.2	11.675	7.24	67.425	281.4 ± 26.9	15.338	---
Spring Post-Runoff, 77 (48 days)	99.701	644.0 ± 27.8	35.101	21.76	N.D.	N.D.	N.D.	N.D.
Summer, 77 (137 days)	113.392	1969.0 ± 42.7	107.320	66.52	N.D.	N.D.	N.D.	N.D.

N.F. = No flow during this period.

N.D. = No data collected.

* = Total area drained = 18.35 ha; Area irrigated = 2.4 ha; Unit area load calculated using total area drained; Most irrigation occurred in spring post runoff and summer periods.

** = Percent of annual load calculated by adding seasonal values and dividing, not by separately calculated water year data.

TABLE 7: DATA SUMMARY FOR STREAM EXPORT OF SODIUM AND CALCIUM FOR THE FORESTED SPRAY SITE.

	SODIUM				CALCIUM			
	Weighted Mean (mg/l)	Total Load (kg/yr or season)	Unit Area Load (kg/ha/yr or season)*	% of Annual Load**	Weighted Mean (mg/l)	Total Load (kg/yr or season)	Unit Area Load (kg/ha/yr or season)*	% of Annual Load**
1976-77 WATER YEAR	52.586	1549.8 ± 296.2	84.472	* *	63.904	1883.4 ± 167.5	102.654	* *
Fall, 76 (62 days)	72.042	87.43 ± 27.95	4.765	5.64	66.409	80.60 ± 27.80	4.393	4.28
Winter, 76-77 (77 days)	N.F.	N.F.	N.F.	0	N.F.	N.F.	N.F.	0
Spring Runoff, 77 (41 days)	22.849	95.36 ± 11.66	5.20	6.16	60.242	251.41 ± 34.64	13.703	13.35
Spring Post Runoff, 77 (48 days)	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Summer, 77 (137 days)	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.

N.F. = No flow during this period.

N.D. = No data collected.

* = Total area drained = 18.35 ha; Area irrigated = 2.4 ha; Unit area load calculated using total area drained; Most irrigation occurred in spring post runoff and summer periods.

** = Percent of annual load calculated by dividing by separately calculated water year data.

TABLE 18. DATA SUMMARY FOR STREAM EXPORT OF TOTAL PHOSPHORUS FOR THE FELTON DRAIN STATIONS.

	INPUT STATION (02)				OUTPUT STATION (10)			
	Weighted Mean (mg/l)	Total Load (kg/yr or season)	Unit Area Load (kg/ha/yr or season)	% of Annual Load***	Weighted Mean (mg/l)	Total Load (kg/yr or season)	Added Unit Area Load (kg/ha/yr or season)**	% of Annual Load***
1975-76 WATER YEAR*	0.084	5.992 ± .703	0.111	***	0.064	13.521 ± 1.566	0.089	***
Fall, 75 (62 days)	0.076	0.564 ± .149	0.010	11.30	0.059	0.429 ± .259	-0.002	---
Winter, 75-76 (59 days)	N.F.	N.F.	N.F.	N.F.	0.040	0.775 ± .199	0.009	---
Spring Runoff, 76 (62 days)	0.100	3.616 ± .278	0.067	72.46	0.053	5.513 ± .432	0.022	---
Spring Post-Runoff, 76 (46 days)	0.047	0.587 ± .067	0.011	11.76	0.080	4.588 ± .406	0.047	---
Summer, 76 (137 days)	0.111	0.223 ± .054	0.004	4.47	0.157+	15.634 ± .317+	---	---
1976-77 WATER YEAR	0.374	5.350 ± 5.132	0.100	---	1.271+	516.51 ± 193.44+	---	---
Fall, 76 (62 days)	N.F.	N.F.	N.F.	N.F.	N.D.	N.D.	N.D.	N.D.
Winter, 76-77 (68 days)	N.F.	N.F.	N.F.	N.F.	0.254+	22.72 ± 1.90+	---	---
Spring Runoff, 77 (53 days)	0.374	4.559 ± .745	0.085	---	1.094+	151.71 ± 4.62+	---	---
Spring Post-Runoff, 77 (46 days)	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Summer, 77 (137 days)	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.

N.F. = No flow during this period.
N.D. = No data collected.
+ = Includes lake discharge also.
* = 1975-76 water year calculated from August 28, 1975 to August 27, 1976 to avoid including lake discharge.
** = Added unit area load is load contributed by spray site (output load minus input load).
*** = Percent of annual load calculated by adding seasonal values and dividing, not by separately calculated water year data.

TABLE 19: DATA SUMMARY FOR STREAM EXPORT OF MOLYBDATE REACTIVE PHOSPHORUS FOR THE FELTON DRAIN STATIONS.

	INPUT STATION (2)				OUTPUT STATION (10)			
	Weighted Mean (mg/l)	Total Load (kg/yr or season)	Unit Area Load (kg/ha/yr or season)	% of Annual Load***	Weighted Mean (mg/l)	Total Load (kg/yr or season)	Added Unit Area Load (kg/ha/yr or season)**	% of Annual Load***
1975-76 WATER YEAR*	0.036	2.602 ± .342	0.048	***	0.016	3.409 ± .506	0.010	***
Fall, 75 (62 days)	0.063	0.468 ± .156	0.009	23.42	0.049	0.361 ± .269	-0.001	---
Winter, 75-76 (59 days)	N.F.	N.F.	N.F.	N.F.	0.017	0.324 ± .144	0.637	---
Spring Runoff, 76 (62 days)	0.035	1.253 ± .111	0.023	62.71	0.008	0.817 ± .062	-0.005	---
Spring Post Runoff, 76 (46 days)	0.014	0.174 ± .023	0.003	8.71	0.020	1.167 ± .143	0.012	---
Summer, 76 (137 days)	0.051	0.103 ± .044	0.002	5.16	0.094+	9.394 ± 1.006+	---	---
1976-77 WATER YEAR	0.248	3.542 ± 3.888	0.066	---	0.849+	344.95 ± 104.28+	---	---
Fall, 76 (62 days)	N.F.	N.F.	N.F.	N.F.	N.D.	N.D.	---	---
Winter, 76-77 (68 days)	N.F.	N.F.	N.F.	N.F.	0.190+	16.97 ± 1.71+	---	---
Spring Runoff, 77 (53 days)	0.248	3.018 ± .565	0.056	---	1.094+	151.71 ± 4.62+	---	---
Spring Post Runoff, 77 (46 days)	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Summer, 77 (137 days)	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.

N.F. = No flow during this period.
N.D. = No data collected.
+ = Includes lake discharge also.
* = 1975-76 water year calculated from August 28, 1975 to August 27, 1976 to avoid including lake discharge.
** = Added unit area load is load contributed by spray site (output load minus input load).
*** = Percent of annual load is calculated by adding seasonal values and dividing, not by separately calculated water year data.

TABLE 20: DATA SUMMARY FOR STREAM EXPORT OF NITRATE-NITROGEN FOR THE FELTON DRAIN STATIONS.

	INPUT STATION (2)				OUTPUT STATION (10)			
	Weighted Mean (mg/l)	Total Load (kg/yr or season)	Unit Area Load (kg/ha/yr or season)	% of Annual Load***	Weighted Mean (mg/l)	Total Load (kg/yr or season)	Added Unit Area Load (kg/ha/yr or season)**,	% of Annual Load***
1975-76 WATER YEAR*	3.566	255.51 ± 47.91	4.752	***	1.812	382.87 ± 30.99	1.510	***
Fall, 75 (62 days)	1.527	11.28 ± 2.89	0.210	5.04	1.416	10.35 ± 5.65	-0.011	---
Winter, 75-76 (59 days)	N.F.	N.F.	N.F.	N.F.	0.465	8.91 ± 1.22	0.106	---
Spring Runoff, 76 (62 days)	2.743	99.14 ± 11.65	1.844	44.30	2.154	225.90 ± 9.91	1.503	---
Spring Post Runoff, 76 (46 days)	7.677	96.35 ± 10.62	1.792	43.06	1.527	87.38 ± 6.94	-0.106	---
Summer, 76 (137 days)	8.457	17.01 ± 2.26	0.316	7.60	0.292+	29.08 ± 5.01+	---	---
1976-77 WATER YEAR	4.684	66.93 ± 56.32	1.245	---	3.643+	1480.4 ± 138.37+	---	---
Fall, 76 (62 days)	N.F.	N.F.	N.F.	N.F.	N.D.	N.D.	---	---
Winter, 76-77 (68 days)	N.F.	N.F.	N.F.	N.F.	0.852+	76.27 ± 9.46+	---	---
Spring Runoff, 77 (53 days)	4.684	57.03 ± 8.18	1.061	---	4.046+	560.86 ± 16.57+	---	---
Spring Post Runoff, 77 (46 days)	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Summer, 77 (137 days)	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.

N.F. = No flow during this period.
N.D. = No data collected.
+ = Includes lake discharge also.
* = 1975-76 water year calculated from August 28, 1975 to August 27, 1976 to avoid including lake discharge.
** = Added unit area load is load contributed by spray site (output load minus input load).
*** = Percent of annual load is calculated by adding seasonal values and dividing, not by separately calculated water year data.

TABLE 21: DATA SUMMARY FOR STREAM EXPORT OF NITRITE-NITROGEN FOR THE FELTON DRAIN STATIONS.

	INPUT STATION (2)				OUTPUT STATION (10)			
	Weighted Mean (mg/l)	Total Load (kg/yr or season)	Unit Area Load (kg/ha/yr or season)	% of Annual Load***	Weighted Mean (mg/l)	Total Load (kg/yr or season)	Added Unit Area Load (kg/ha/yr or season)**	% of Annual Load***
1975-76 WATER YEAR*	0.035	2.534 ± .828	0.047	---	0.044	9.262 ± .943	0.080	***
Fall, 75 (62 days)	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	---
Winter, 75-76 (59 days)	N.F.	N.F.	N.F.	N.F.	0.045	0.871 ± .284	0.010	---
Spring Runoff, 76 (62 days)	0.016	0.588 ± .041	0.011	---	0.041	4.256 ± .226	0.044	---
Spring Post Runoff, 76 (46 days)	0.079	0.991 ± .210	0.018	---	0.042	2.378 ± .244	0.016	---
Summer, 76 (137 days)	0.114	0.228 ± .051	0.004	---	0.023+	2.281 ± .545+	---	---
1976-77 WATER YEAR	0.243	3.469 ± 5.125	0.065	---	0.128+	52.006 ± 9.550+	---	---
Fall, 76 (62 days)	N.F.	N.F.	N.F.	N.F.	N.D.	N.D.	---	---
Winter, 76-77 (68 days)	N.F.	N.F.	N.F.	N.F.	0.025+	2.218 ± .696+	---	---
Spring Runoff, 77 (53 days)	0.243	2.956 ± .744	0.055	---	0.146+	20.174 ± 1.574+	---	---
Spring Post Runoff, 77 (46 days)	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Summer, 77 (137 days)	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.

N.F. = No flow during this period.
N.D. = No data collected.
+ = Includes lake discharge also.
* = 1975-76 water year calculated from August 28, 1975 to August 27, 1976 to avoid including lake discharge.
** = Added unit area load is load contributed by spray site (output load minus input load).
*** = Percent of annual load is calculated by adding seasonal values and dividing, not by separately calculated water year data.

TABLE 22: DATA SUMMARY FOR STREAM EXPORT OF AMMONIA-NITROGEN FOR THE FELTON DRAIN STATIONS.

	INPUT STATION (2)				OUTPUT STATION (10)			
	Weighted Mean (mg/l)	Total Load (kg/yr or season)	Unit Area Load (kg/ha/yr or season)	% of Annual Load***	Weighted Mean (mg/l)	Total Load (kg/yr or season)	Added Unit Area Load (kg/ha/yr or season)**	% of Annual Load***
1975-76 WATER YEAR*	0.042	3.043 ± .987	0.057	***	0.038	8.004 ± 1.203	0.059	***
Fall, 75 (62 days)	0.037	0.275 ± 1.139	0.005	11.31	0.090	0.659 ± .683	0.005	---
Winter, 75-76 (59 days)	N.F.	N.F.	N.F.	N.F.	0.077	1.465 ± .322	0.017	---
Spring Runoff, 76 (62 days)	0.039	1.414 ± .248	0.026	58.17	0.030	3.117 ± .358	0.037	---
Spring Post Runoff, 76 (46 days)	0.057	0.721 ± .093	0.013	29.66	0.035	2.016 ± .265	0.024	---
Summer, 76 (137 days)	0.010	0.021 ± .006	0.0004	0.86	0.030+	3.008 ± .570+	---	---
1976-77 WATER YEAR	0.603	8.618 ± 14.395	0.160	---	0.102+	41.248 ± 43.358+	---	---
Fall, 76 (62 days)	N.F.	N.F.	N.F.	N.F.	N.D.	N.D.	N.D.	N.D.
Winter, 76-77 (68 days)	N.F.	N.F.	N.F.	N.F.	0.035+	3.155 ± .405+	---	---
Spring Runoff, 77 (53 days)	0.603	7.344 ± 2.090	0.137	---	0.164+	22.792 ± 1.899+	---	---
Spring Post Runoff, 77 (46 days)	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Summer, 77 (137 days)	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.

N.F. = No flow during this period.
N.D. = No data collected.
+ = Includes lake discharge also.
* = 1975-76 water year calculated from August 28, 1975 to August 27, 1976 to avoid including lake discharge.
** = Added unit area load is load contributed by spray site (output load minus input load).
*** = Percent of annual load is calculated by adding seasonal values and dividing, not by separately calculated water year data.

TABLE 23: DATA SUMMARY FOR STREAM EXPORT OF KJELDAHL NITROGEN FOR THE FELTON DRAIN STATIONS.

	INPUT STATION (2)				OUTPUT STATION (10)			
	Weighted Mean (mg/l)	Total Load (kg/yr or season)	Unit Area Load (kg/ha/yr or season)	% of Annual Load***	Weighted Mean (mg/l)	Total Load (kg/yr or season)	Added Unit Area Load (kg/ha/yr or season)**	% of Annual Load***
1975-76 WATER YEAR*	1.366	97.83 ± 5.60	1.820	***	1.129	238.64 ± 7.46	1.669	***
Fall, 75 (62 days)	0.985	7.28 ± 1.65	0.135	8.92	0.947	6.92 ± 1.57	-0.004	---
Winter, 75-76 (59 days)	N.F.	N.F.	N.F.	N.F.	0.728	13.93 ± .64	0.165	---
Spring Runoff, 76 (62 days)	1.442	52.12 ± 2.33	0.969	63.89	1.176	123.30 ± 2.51	0.844	---
Spring Post Runoff, 76 (46 days)	1.537	19.29 ± .63	0.359	23.65	1.129	64.61 ± 1.61	0.537	---
Summer, 76 (137 days)	1.435	2.89 ± .22	0.054	3.54	1.127+	112.32 ± 1.67+	---	---
1976-77 WATER YEAR	2.087	29.82 ± 30.44	0.555	---	2.986+	1213.3 ± 1078.1+	---	---
Fall, 76 (62 days)	N.F.	N.F.	N.F.	N.F.	N.D.	N.D.	---	---
Winter, 76-77 (68 days)	N.F.	N.F.	N.F.	N.F.	0.908+	81.31 ± 2.11+	---	---
Spring Runoff, 77 (53 days)	2.087	25.41 ± 4.42	0.473	---	1.816+	251.70 ± 19.27+	---	---
Spring Post Runoff, 77 (46 days)	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Summer, 77 (137 days)	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.

N.F. = No flow during this period.
N.D. = No data collected.
+ = Includes lake discharge also.
* = 1975-76 water year calculated from August 28, 1975 to August 27, 1976 to avoid including lake discharge.
** = Added unit area load is load contributed by spray site (output load minus input load).
*** = Percent of annual load is calculated by adding seasonal values and dividing, not by separately calculated water year data.

TABLE 24: DATA SUMMARY FOR STREAM EXPORT OF CHLORIDE FOR THE FELTON DRAIN STATIONS.

	INPUT STATION (2)				OUTPUT STATION (10)			
	Weighted Mean (mg/l)	Total Load (kg/yr or season)	Unit Area Load (kg/ha/yr or season)	% of Annual Load***	Weighted Mean (mg/l)	Total Load (kg/yr or season)	Added Unit Area Load (kg/ha/yr or season)**	% of Annual Load***
1975-76 WATER YEAR*	100.566	7204.9 ± 937.6	134.01	***	71.640	15141.1 ± 855.4	94.09	***
Fall, 75 (62 days)	177.604	1312.1 ± 738.7	24.40	24.64	85.108	622.3 ± 335.2	-8.18	---
Winter, 75-76 (59 days)	N.F.	N.F.	N.F.	N.F.	185.584	3552.6 ± 382.6	42.12	---
Spring Runoff, 76 (62 days)	86.573	3128.4 ± 258.7	58.19	58.75	71.318	7478.3 ± 246.6	51.57	---
Spring Post Runoff, 76 (46 days)	61.168	767.7 ± 42.0	14.28	14.42	57.485	3289.4 ± 130.8	29.90	---
Summer, 76 (137 days)	57.969	116.6 ± 5.1	2.17	2.19	103.111+	10276.0 ± 217.5+	---	---
1976-77 WATER YEAR	98.696	1410.3 ± 1020.4	26.23	---	95.936+	38984.6 ± 3119.0+	---	---
Fall, 76 (62 days)	N.F.	N.F.	N.F.	N.F.	N.D.	N.D.	N.D.	N.D.
Winter, 76-77 (68 days)	N.F.	N.F.	N.F.	N.F.	N.D.	N.D.	N.D.	N.D.
Spring Runoff, 77 (53 days)	98.696	1201.8 ± 159.6	22.35	---	97.795+	13557.4 ± 217.2+	---	---
Spring Post Runoff, 77 (46 days)	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Summer, 77 (137 days)	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.

N.F. = No flow during this period.
N.D. = No data collected.
+ = Includes lake discharge also.
* = 1975-76 water year calculated from August 28, 1975 to August 27, 1976 to avoid including lake discharge.
** = Added unit area load is load contributed by spray site (output load minus input load).
*** = Percent of annual load is calculated by adding seasonal values and dividing, not by separately calculated water year data.

TABLE 25: DATA SUMMARY FOR STREAM EXPORT OF CALCIUM FOR THE FELTON DRAIN STATIONS.

	INPUT STATION (2)				OUTPUT STATION (10)			
	Weighted Mean (mg/l)	Total Load (kg/yr or season)	Unit Area Load (kg/ha/yr or season)	% of Annual Load***	Weighted Mean (mg/l)	Total Load (kg/yr or season)	Added Unit Area Load (kg/ha/yr or season)**	% of Annual Load***
1975-76 WATER YEAR*	66.070	4733.5 ± 553.6	88.04	***	102.137	21586.6 ± 1153.9	199.80	***
Fall, 75 (62 days)	36.587	270.3 ± 266.4	5.03	6.42	105.206	769.3 ± 370.0	5.92	---
Winter, 75-76 (59 days)	N.F.	N.F.	N.F.	N.F.	111.959	2143.2 ± 139.0	25.41	---
Spring Runoff, 76 (62 days)	71.100	2569.3 ± 125.1	47.79	61.07	98.258	10303.2 ± 322.2	91.69	---
Spring Post Runoff, 76 (46 days)	97.711	1226.3 ± 69.7	22.81	29.15	107.404	6146.0 ± 325.8	58.33	---
Summer, 76 (137 days)	70.271	141.3 ± 18.9	2.63	3.36	57.572+	5737.6 ± 408.5+	---	---
1976-77 WATER YEAR	69.660	995.4 ± 832.6	18.50	---	51.329+	20858.2 ± 1011.2+	---	---
Fall, 76 (62 days)	N.F.	N.F.	N.F.	N.F.	44.022+	3598.9 ± 138.2+	---	---
Winter, 76-77 (68 days)	N.F.	N.F.	N.F.	N.F.	41.912+	3752.5 ± 75.3+	---	---
Spring Runoff, 77 (53 days)	69.660	848.3 ± 120.9	15.80	---	52.596+	7291.4 ± 190.8+	---	---
Spring Post Runoff, 77 (46 days)	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Summer, 77 (137 days)	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.

N.F. = No flow during this period.
N.D. = No data collected.
+ = Includes lake discharge also.
* = 1975-76 water year calculated from August 28, 1975 to August 27, 1976 to avoid including lake discharge.
** = Added unit area load is load contributed by spray site (output load minus input load).
*** = Percent of annual load is calculated by adding seasonal values and dividing, not by separately calculated water year data.

TABLE 26: DATA SUMMARY FOR STREAM EXPORT OF SODIUM FOR THE FELTON DRAIN STATIONS.

	INPUT STATION (2)				OUTPUT STATION (10)			
	Weighted Mean (mg/l)	Total Load (kg/yr or season)	Unit Area Load (kg/ha/yr or season)	% of Annual Load***	Weighted Mean (mg/l)	Total Load (kg/yr or season)	Added Unit Area Load (kg/ha/yr or season)**	% of Annual Load***
1975-76 WATER YEAR*	62.231	4458.4 ± 1164.2	82.924	***	48.571	10265.3 ± 829.9	68.843	***
Fall, 75 (62 days)	78.453	570.6 ± 456.4	10.780	17.51	52.904	386.8 ± 205.2	-2.286	---
Winter, 75-76 (59 days)	N.F.	N.F.	N.F.	N.F.	147.188	2817.6 ± 419.5	33.41	---
Spring Runoff, 76 (62 days)	60.879	2199.9 ± 427.8	40.917	66.48	45.919	4815.0 ± 178.7	31.00	---
Spring Post Runoff, 76 (46 days)	36.529	458.4 ± 35.4	8.526	13.85	33.855	1937.3 ± 147.2	22.97	---
Summer, 76 (137 days)	35.499	71.4 ± 6.0	1.328	2.16	76.901+	7664.0 ± 377.0+	---	---
1976-77 WATER YEAR	72.221	1032.0 ± 1101.6	19.195	---	82.348+	33463.0 ± 1244.3+	---	---
Fall, 76 (62 days)	N.F.	N.F.	N.F.	N.F.	80.963+	6619.0 ± 69.8+	---	---
Winter, 76-77 (68 days)	N.F.	N.F.	N.F.	N.F.	103.797+	9293.1 ± 104.0+	---	---
Spring Runoff, 77 (53 days)	72.221	879.5 ± 160.0	16.36	---	81.355+	11278.3 ± 226.0+	---	---
Spring Post Runoff, 77 (46 days)	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Summer, 77 (137 days)	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.

N.F. = No flow during this period.
N.D. = No data collected.
\+ = Includes lake discharge also.
* = 1975-76 water year calculated from August 28, 1975 to August 27, 1976 to avoid including lake discharge.
** = Added unit area load is load contributed by spray site (output load minus input load).
*** = Percent of annual load is calculated by adding seasonal values and dividing, not by separately calculated water year data.

TABLE 2 7: DATA SUMMARY FOR STREAM EXPORT OF SUSPENDED SOLIDS FOR THE FELTON DRAIN STATIONS.

	INPUT STATION (2)				OUTPUT STATION (10)			
	Weighted Mean (mg/l)	Total Load (kg/yr or season)	Unit Area Load (kg/ha/yr or season)	% of Annual Load***	Weighted Mean (mg/l)	Total Load (kg/yr or season)	Added Unit Area Load (kg/ha/yr or season)**	% of Annual Load***
1975-76 WATER YEAR*	15.498	1110.3 ± 369.0	20.651	***	14.544	3073.8 ± 394.1	23.278	***
Fall, 75 (62 days)	16.713	123.5 ± 181.2	2.297	14.	9.831	71.9 ± 16.3	-0.612	---
Winter, 75-76 (59 days)	N.F.	N.F.	N.F.	N.F.	4.789	91.7 ± 31.6	1.087	---
Spring Runoff, 76 (62 days)	15.260	551.4 ± 111.7	10.256	62.68	12.475	1308.1 ± 60.1	8.971	---
Spring Post Runoff, 76 (46 days)	15.567	195.4 ± 72.1	3.634	22.21	17.572	1005.5 ± 117.6	9.604	---
Summer, 76 (137 days)	4.649	9.4 ± 6.4	0.175	1.07	6.593+	657.1 ± 117.6+	---	---
1976-77 WATER YEAR	18.926	270.4 ± 591.7	5.029	---	11.923+	4845.2 ± 1750.4+	---	---
Fall, 76 (62 days)	N.F.	N.F.	N.F.	N.F.	4.172+	341.1 ± 39.7+	---	---
Winter, 76-77 (68 days)	N.F.	N.F.	N.F.	N.F.	4.319+	386.7 ± 27.1+	---	---
Spring Runoff, 77 (53 days)	18.926	230.5 ± 85.9	4.287	---	18.743+	2598.4 ± 528.5+	---	---
Spring Post Runoff, 77 (46 days)	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Summer, 77 (137 days)	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.

N.F. = No flow during this period.
N.D. = No data collected.
+ = Includes lake discharge also.
* = 1975-76 water year calculated from August 28, 1975 to August 27, 1976 to avoid including lake discharge.
** = Added unit area load is load contributed by spray site (output load minus input load).
*** = Percent of annual load is calculated by adding seasonal values and dividing, not by separately calculated water year data.

10.2.5/11.2.5 BASELINE WATERSHED STUDIES

The runoff from a non-irrigated old field watershed was also studied as background data for this project. These data are presented in Tables 28-32 and represent the lowest loadings to be expected from watersheds in this area since much of the native N and P were "mined" by farming prior to abandonment of this site. Water budget calculations suggest that nearly all input water not lost by evapotranspiration is lost by "stream" export by way of the still functional tile system and little groundwater recharge occurred from this watershed. This lack of significant recharge was the result of an apparently almost continuous clay lens underlying the watershed and the still functional tile.

10.2.6/11.2.6 WINTER IRRIGATION STUDIES

From the results of this study, a number of conclusions can be drawn concerning the impact of secondary municipal sewage effluent irrigation on an unmodified natural watershed during northern winters. Soil frost penetration into the soil was apparently prevented by beginning irrigation early in the winter season which subsequently built up a protective ice pack. This procedure allowed significant infiltration from ice melt at the ground surface to occur throughout the winter on a site which had good infiltration characteristics, and runoff volume was reduced as a result. Site saturation evident at the end of the winter operations could impair spring irrigation operations. Groundwater and runoff quality was poor during the winter periods compared to the rest of the year. Nitrate accumulation occurred in the groundwater and levels could ultimately exceed the standard of 10 mg-N/l, although they did not in this experiment. In terms of total mass applied, effective phosphorus renovation occurred during winter operations but high concentrations in surface runoff exceeded 1.0 mg-P/l.

Irrigation during the winter months with low nitrogen wastewater is an obvious solution to the nitrogen infiltration problem. This low nitrogen wastewater is available in the WQMP lake system in the late fall as a result of lake mediated N stripping processes, and irrigation from the end of the lake system could continue into the winter months while new effluent is taken in at the head of the lake system. Winter irrigation for phosphorus removal could proceed until the lake effluent nitrogen concentration reaches 10 mg-N/l, effectively increasing the operating season of the system by several months. Phosphorus retention could be enhanced by diking or contour plowing to increase soil contact. Winter wastewater irrigation can therefore be a potentially viable management option for operation of a combined land-lake treatment system for nitrogen and phosphorus renovation.

10.2.7/11.2.7 MILL CREEK

The data indicated that most of the sediment transport occurs in the winter and spring when runoff is largest. The quantity of pesticides (DDT, DDE and Atrazine) and suspended sediment leaving the watershed suggest that the suspended sediment loss is directly proportional to the magnitude of the surface runoff. Because of its mode of transport, one would expect that the

TABLE 28: DATA SUMMARY FOR STREAM EXPORT OF TOTAL AND MOLYBDATE REACTIVE PHOSPHORUS FOR THE 7.73 ha BASELINE WATERSHED.

	TOTAL P				MOLYBDATE REACTIVE P			
	Weighted Mean (mg/l)	Total Load (kg/yr or season)	Unit Area Load (kg/ha/yr or season)	% of Annual Load **	Weighted Mean (mg/l)	Total Load (kg/yr or season)	Unit Area Load (kg/ha/yr or season)	% of Annual Load**
1975-76 WATER YEAR	0.073	1.369 ± .264	0.177	* *	0.028	0.526 ± .124	0.068	* *
Fall, 75 (62 days)	0.069	0.107 ± .086	0.014	8.80	0.063	0.098 ± .087	0.013	20.21
Winter, 75-76 (59 days)	N.F.	N.F.	N.F.	N.F.	N.F.	N.F.	N.F.	N.F.
Spring Runoff, 76 (62 days)	0.067	0.634 ± .045	0.082	52.14	0.022	0.208 ± .013	0.027	42.89
Spring Post-Runoff, 76 (46 days)	0.074	0.359 ± .077	0.046	29.52	0.028	0.136 ± .046	0.018	28.04
Summer, 76 (137 days)	0.193	0.116 ± .662	0.015	9.53	0.071	0.043 ± .241	0.006	8.87
1976-77 WATER YEAR	0.133	0.474 ± .199	0.061	---	0.043	0.152 ± .050	0.020	---
Fall, 76 (62 days)	N.F.	N.F.	N.F.	N.F.	N.F.	N.F.	N.F.	N.F.
Winter, 76-77 (68 days)	N.F.	N.F.	N.F.	N.F.	N.F.	N.F.	N.F.	N.F.
Spring Runoff, 77 (53 days)	0.133	0.325 ± .029	0.042	---	0.043	0.105 ± .007	0.014	---
Spring Post-Runoff, 77 (46 days)	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Summer, 77 (137 days)	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.

N.F. = No flow during this period.
N.D. = No data collected.

** = Percent of annual load calculated by adding seasonal values and dividing by sum not by separately calculated water year data.

TABLE 29: DATA SUMMARY FOR STREAM EXPORT OF NITRATE AND AMMONIA NITROGEN FOR THE 7.73 ha BASELINE WATERSHED.

	NITRATE-NITROGEN				AMMONIA-NITROGEN			
	Weighted Mean (mg/l)	Total Load (kg/yr or season)	Unit Area Load (kg/ha/yr or season)	% of Annual Load**	Weighted Mean (mg/l)	Total Load (kg/yr or season)	Unit Area Load (kg/ha/yr or season)	% of Annual Load**
1975-76 WATER YEAR	0.047	0.891 ± .130	0.115	* *	0.078	1.458 ± .866	0.189	* *
Fall, 75 (62 days)	0.106	0.165 ± .103	0.021	20.60	0.011	0.017 ± .038	0.002	1.28
Winter, 75-76 (59 days)	N.F.	N.F.	N.F.	N.F.	N.F.	N.F.	N.F.	N.F.
Spring Runoff, 76 (62 days)	0.048	0.453 ± .022	0.059	56.55	0.046	0.441 ± .054	0.057	33.21
Spring Post-Runoff, 76 (46 days)	0.027	0.131 ± .019	0.017	16.35	0.174	0.842 ± .397	0.109	63.40
Summer, 76 (137 days)	0.087	0.052 ± .395	0.007	6.49	0.047	0.028 ± .113	0.004	2.11
1976-77 WATER YEAR	0.257	0.918 ± .319	0.119	---	0.062	0.233 ± .054	0.029	---
Fall, 76 (62 days)	N.F.	N.F.	N.F.	N.F.	N.F.	N.F.	N.F.	N.F.
Winter, 76-77 (68 days)	N.F.	N.F.	N.F.	N.F.	N.F.	N.F.	N.F.	N.F.
Spring Runoff, 77 (53 days)	0.257	0.630 ± .046	0.082	---	0.062	0.153 ± .008	0.020	---
Spring Post-Runoff, 77 (46 days)	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Summer, 77 (137 days)	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.

N.F. = No flow during this period.
N.D. = No data collected.
** = Percent of annual load calculated by adding seasonal values and dividing, not by separately calculated water year data.

TABLE 30: DATA SUMMARY FOR STREAM EXPORT OF NITRITE AND TOTAL KJELDAHL NITROGEN FOR THE 7.73 ha BASELINE WATERSHED.

	NITRITE-NITROGEN				TOTAL KJELDAHL NITROGEN			
	Weighted Mean (mg/l)	Total Load (kg/yr or season)	Unit Area Load (kg/ha/yr or season)	% of Annual Load**	Weighted Mean (mg/l)	Total Load (kg/yr or season)	Unit Area Load (kg/ha/yr or season	% of Annual Load**
1975-76 WATER YEAR	0.017	0.310 ± .196	0.040	* *	0.561	10.545 ± 2.318	1.365	* *
Fall, 75 (62 days)	N.D.	N.D.	N.D.	N.D.	0.479	0.749 ± .270	0.097	7.91
Winter, 75-76 (59 days)	N.F.	N.F.	N.F.	N.F.	N.F.	N.F.	N.F.	N.F.
Spring Runoff, 76 (62 days)	0.018	0.172 ± .047	0.022	---	0.449	4.275 ± .139	0.553	45.15
Spring Post-Runoff, 76 (46 days)	0.014	0.069 ± .028	0.009	---	0.805	3.906 ± 1.036	0.506	41.25
Summer, 76 (137 days)	0.007	0.004 ± .021	0.0005	---	0.892	0.538 ± .985	0.070	5.68
1976-77 WATER YEAR	0.014	0.050 ± .024	0.006	---	0.771	2.755 ± 1.137	0.357	---
Fall, 76 (62 days)	N.F.	N.F.	N.F.	N.F.	N.F.	N.F.	N.F.	N.F.
Winter, 76-77 (68 days)	N.F.	N.F.	N.F.	N.F.	N.F.	N.F.	N.F.	N.F.
Spring Runoff, 77 (53 days)	0.014	0.034 ± .004	0.004	---	0.771	1.890 ± .165	0.245	---
Spring Post-Runoff, 77 (46 days)	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Summer, 77 (137 days)	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.

N.F. = No flow during this period.
N.D. = No data collected.
** = Percent of an annual load calculated by adding seasonal values and dividing, not by separately calculated water year data.

TABLE 31: DATA SUMMARY FOR STREAM EXPORT OF SUSPENDED SOLIDS AND CHLORIDE FOR THE 7.73 ha BASELINE WATERSHED.

	CHLORIDE				SUSPENDED SOLIDS			
	Weighted Mean (mg/l)	Total Load (kg/yr or season)	Unit Area Load (kg/ha/yr or season)	% of Annual Load**	Weighted Mean (mg/l)	Total Load (kg/yr or season)	Unit Area Load (kg/ha/yr or season)	% of Annual Load**
1975-76 WATER YEAR	15.627	293.88 ± 56.89	38.043	* *	11.425	214.86 ± 129.72	27.814	---
Fall, 75 (62 days)	18.377	28.715 ± 35.083	3.717	11.17	N.D.	N.D.	N.D.	N.D.
Winter, 75-76 (59 days)	N.F.	N.F.	N.F.	N.F.	N.F.	N.F.	N.F.	N.F.
Spring Runoff, 76 (62 days)	16.547	157.40 ± 13.97	20.375	61.23	5.454	51.88 ± 6.43	6.716	---
Spring Post-Runoff, 76 (46 days)	14.220	68.981 ± 10.168	8.930	26.83	17.753	86.12 ± 23.95	11.148	---
Summer, 76 (137 days)	3.289	1.985 ± 6.958	0.257	0.77	69.146	41.72 ± 663.80	5.401	---
1976-77 WATER YEAR	56.710*	202.59 ± 81.30*	26.225*	---	14.783	52.81 ± 17.87	6.836	---
Fall, 76 (62 days)	N.F.	N.F.	N.F.	N.F.	N.F.	N.F.	N.F.	N.F.
Winter, 76-77 (68 days)	N.F.	N.F.	N.F.	N.F.	N.F.	N.F.	N.F.	N.F.
Spring Runoff, 77 (53 days)	56.710*	139.00 ± 11.81*	17.994*	---	14.783	36.23 ± 2.59	4.690	---
Spring Post-Runoff, 77 (46 days)	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Summer, 77 (137 days)	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.

N.F. = No flow during this period.
N.D. = No data collected.
* = Apparent contamination from adjacent spray site.
** = Percent of annual load calculated by addition seasonal values and dividing by sum, not by separately calculated water year data.

TABLE 32: DATA SUMMARY FOR STREAM EXPORT OF SODIUM AND CALCIUM FOR THE 7.73 ha BASELINE WATERSHED.

	CALCIUM				SODIUM			
	Weighted Mean (mg/l)	Total Load (kg/yr or season)	Unit Area Load (kg/ha/yr or season)	% of Annual Load**	Weighted Mean (mg/l)	Total Load (kg/yr or season)	Unit Area Load (kg/ha/yr or season)	% of Annual Load**
1975-76 WATER YEAR	36.899	693.93 ± 100.96	89.829	* *	16.629	312.74 ± 77.73	40.484	* *
Fall, 75 (62 days)	59.098	92.35 ± 36.49	11.955	14.53	18.107	28.29 ± 33.00	3.662	11.28
Winter, 75-76 (59 days)	N.F.	N.F.	N.F.	N.F.	N.F.	N.F.	N.F.	N.F.
Spring Runoff, 76 (62 days)	32.990	313.78 ± 18.03	40.619	49.37	18.746	178.31 ± 15.79	23.082	71.09
Spring Post-Runoff, 76 (46 days)	44.140	214.13 ± 24.55	27.719	33.69	8.923	43.29 ± 8.87	5.604	17.26
Summer, 76 (137 days)	25.278	15.253 ± 31.515	1.974	2.40	1.568	0.946 ± 5.146	0.122	0.38
1976-77 WATER YEAR	47.348	169.14 ± 82.99	21.895	---	26.921	96.17 ± 61.65	12.449	---
Fall, 76 (62 days)	N.F.	N.F.	N.F.	N.F.	N.F.	N.F.	N.F.	N.F.
Winter, 76-77 (68 days)	N.F.	N.F.	N.F.	N.F.	N.F.	N.F.	N.F.	N.F.
Spring Runoff, 77 (53 days)	47.348	116.05 ± 12.05	15.023	---	26.921	65.98 ± 8.95	8.541	---
Spring Post-Runoff, 77 (46 days)	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.
Summer, 77 (137 days)	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.

N.F. = No flow during this period.
N.D. = No data collected.
** = Percent of annual load calculated by adding seasonal values and dividing, not by separately calculated water year data.

pesticide adsorbed on the sediment should have a similar relationship to surface runoff. Indeed, this is the case for DDT, however, DDE does not appear to be correlated with surface runoff. This discrepancy in the case of DDE would suggest that variables other than surface runoff influence the transport of this pesticide, e.g., time of application and hence, availability.

Data obtained for the months of May through June suggests that the pesticide transported in solution is the same order of magnitude as that transported on the suspended solids. This result coupled with the fact that our measurements of sediment discharge indicate that the major movement of sediment occurs in the winter and spring when stream flow rates are largest, would indicate that the winter-spring season is potentially the period of maximum pesticide transport.

One can tentatively conclude that the only significant pesticide movement from the watershed would include the no longer used and persistent chlorinated hydrocarbons and the herbicide Atrazine. The only organophosphate found is Guthion. No other classes of pesticides have been detected.

The magnitude of the suspended sediment leaving the watershed does not pose a serious problem when considered alone, but is apparently quite important when considered as a transport agent. Since most of the suspended sediment is transported during the winter-spring period, it is evident that the potential for adsorbed pesticides to be transported is greatest in these seasons. Of course, the degree to which this potential is realized is determined by the availability of pesticides.

Loads for nutrients from Mill Creek are shown in Tables 33-35. No loads for pesticides are available at this time. Recalculation using IJC suggested techniques requires extensive data reformatting and results will not be available until April 1978.

10.3/11.3 POINT:NON-POINT DISTRIBUTION

Data from both Mill Creek and the Felton-Herron Studies reflect non-point sources only.

10.4/11.4 RELATIVE SIGNIFICANCE OF LAND USES AND PRACTICES

"Single" land uses are being studies thus relative significance comparisons will have to be made with outputs from other studies. The relative significance of practices within wastewater irrigation sites can be compared as well as comparisons between the output of wastewater irrigation sites and conventional secondary and tertiary treatment plants.

10.5/11.5 DELIVERY RATIO

We have no data base wtih which to calculate delivery ration from either Mill Creek or Felton-Herron Creek to the mouth of the Grand River, Michigan.

Table 33: Stream Export of Materials by the 889 ha North Branch Subwatershed of Mill Creek.

	1975 - 76			1976 - 77		
	Weighted Mean (mg/l)	Total Load (kg/yr)	Unit Area Load (kg/ha/yr)	Weighted Mean (mg/l)	Total Load (kg/yr)	Unit Area Load (kg/ha/yr)
Nitrate-N	1.191	3529 ± 1433	3.970	0.885	568 ± 66	0.639
Nitrite-N	0.038	113 ± 137	0.127	0.010	6.38 ± .11	0.007
Ammonia-N	0.073	215 ± 229	0.242	0.010	6.61 ± .34	0.007
Total Kjeldahl-N	0.696	2063 ± 938	2.321	0.465	299 ± 52	0.336
Molybdate Reactive P	0.073	217 ± 99	0.244	0.050	32.1 ± 12.5	0.036
Total P	0.171	506 ± 335	0.569	0.054	34.5 ± 14.1	0.039
Chloride	13.585	40246 ± 13602	45.271	30.527	19602 ± 1169	22.049
Calcium	53.698	159078 ± 42395	178.940	*	*	*
Sodium	6.687	19811 ± 5105	22.285	*	*	*
Suspended Solids	21.490	63665 ± 23995	71.614	*	*	*

* = Insufficient data.

Table 34: Stream Export of Materials by the 1146 ha Mill Creek Watershed Above the Confluence with North Branch.

	1975 - 76			1976 - 77		
	Weighted Mean (mg/l)	Total Load (kg/yr)	Unit Area Load (kg/ha/yr)	Weighted Mean (mg/l)	Total Load (kg/yr)	Unit Area Load (kg/ha/yr)
Nitrate-N	1.511	5200 ± 2836	4.538	5.607	4061 ± 2316	3.544
Nitrite-N	0.013	44.2 ± 40.5	0.039	0.009	6.78 ± 1.74	0.006
Ammonia-N	0.100	344 ± 416	0.300	0.013	9.26 ± 12.10	0.008
Total Kjeldahl-N	0.798	2745 ± 731	2.395	1.175	851 ± 301	0.743
Molybdate reactive P	0.063	216 ± 105	0.188	0.156	113 ± 43	0.099
Total P	0.139	478 ± 238	0.417	0.248	179 ± 109	0.156
Chloride	9.875	33986 ± 4377	29.656	19.265	13954 ± 2969	12.176
Calcium	42.438	146055 ± 25920	127.448	44.060	31913 ± 15662	27.847
Sodium	3.781	13012 ± 1605	11.354	3.807	2757 ± 1256	2.406
Suspended Solids	16.388	56399 ± 35775	49.214	33.803	24484 ± 73338	21.365

Table 35: Stream Export of Materials by the 3058 ha Mill Creek Watershed Above M-37.

	1975 - 76			1976 - 77		
	Weighted Mean (mg/l)	Total Load (kg/yr)	Unit Area Load (kg/ha/yr)	Weighted Mean (mg/l)	Total Load (kg/yr)	Unit Area Load (kg/ha/yr)
Nitrate-N	1.765	20573 ± 5546	6.729	3.656	11786 ± 3496	3.854
Nitrite-N	0.025	288 ± 285	0.094	0.010	31.24 ± 3.58	0.010
Ammonia-N	0.078	912 ± 1023	0.298	0.020	62.95 ± 27.72	0.021
Total Kjeldahl N	0.782	9116 ± 2295	2.981	1.117	3602 ± 1090	1.178
Molybdate Reactive P	0.076	882 ± 298	0.288	0.181	582 ± 250	0.190
Total P	0.153	1782 ± 1018	0.583	0.313	1008 ± 331	0.330
Chloride	11.778	137303 ± 23509	44.900	19.808	63863 ± 8334	20.884
Calcium	49.676	579095 ± 111673	189.371	51.314	165439 ± 56926	54.100
Sodium	5.482	63901 ± 8939	20.896	5.984	19293 ± 3644	6.309
Suspended Solids	11.590	135114 ± 137425	44.184	47.985	154709 ± 146989	50.592

We have a substantial data base to calculate the delivery ratio between the constituents in wastewater input and those that ultimately reach surface or groundwater. We support the notion of assuming a long-term delivery ratio of unity for phosphorus after it reaches a stream. For nitrate we assume a delivery ratio of unity between the subsoil (below the root zone) and groundwater. Furthermore, at this time we assume a delivery ratio of unity through the entire soil column during the winter months for nitrate.

10.6/11.6 TO WHAT DEGREE ARE THESE POLLUTANTS TRANSMITTED FROM SOURCES TO BOUNDARY WATERS

This section would relate only to the Mill Creek Study and since sampling stations were not established on the lower Grand River, answers to this question would be speculative.

10.7/11.7 TRANSFERABILITY

Data from both the Mill Creek and Felton-Herron Creek Should have transferability. The needed information at this time is adequate land use data from other parts of the basin.

12.0 RECOMMENDATIONS

12.1 FELTON-HERRON CREEK

Developing at an accelerating rate in the Great Lakes drainage basin are alternatives to the traditional waste treatment plants in the form of land disposal of wastes. These offer the potential of producing an end product that does not contain those elements recognized as detrimental to the eventual receiving waters. They also offer the important option of converting those nutrient elements which are becoming increasingly expensive and in short supply into food and fiber for reuse. There are numerous examples of wastewater systems based on land disposal and the uptake of nutrient materials by plants and animal associations.

It is believed that the use of land and natural ecosystems to recycle and reclaim the elements of our wastewaters will find increasing acceptance to the point of becoming an important adjunct in the treatment of domestic wastes in the Great Lakes basin. Because of the potential of this method, as well as the array of unknown factors associating with its use, land disposal of wastes in all of its ramifications must be subjected to thorough evaluation of all known facets in a critical and searching manner.

With this information a decision on disposal of wastewaters on land with its new and different techniques can be established on the sound scientific basis. Thus we can avoid management practices that might prove, in a few years, to have jeopardized water resources of land ecosystems to a point that they might become irreversible within the lifetime of the present generation.

Recommendations stemming from the Felton-Herron Studies can be summarized as follows:

Overall, the old field and cropland sites resulted in discharges greater than non-irrigated sites but areas affected by this land use are small. Proper selection of vegetation, of irrigation rate and of harvest management would minimize discharges of N and P. Removal of vegetative material minimizes reliance of the sites capacity to retain the nutrients against the recharge flow.

Several general conclusions can be made. These include:

(1) The type of crop selected is very important in management of land irrigation systems for the prevention of NO_3-N losses.
   (A) Annuals such as corn do not take up much N during the early part of the growing season. Thus, such crops should be irrigated at rates that will just replace evapotranspirational losses (about 2.5 cm/week in Michigan) for the early growth period with increased irrigation up to 7.5 cm/week after about the first 8 weeks of growth.

(B) Perennial grasses are the most effective vegetation at removing N from wastewater. Harvesting can extend active uptake through October. Thus, effective N removal by vegetative uptake can be expected from April through October with proper managements with rates up to 10 cm/week of wastewater application.

(C) Legumes such as alfalfa are about as effective as perennial grasses at N removal except that irrigation should be limited to 2.5 cm/week for a 3 week period after harvest since uptake is reduced during this period.

(2) Soils are effective at P sorption so that P concentrations of water leaching past the root zone on irrigated sites approaches background levels. Thus, groundwater loading with P is a function of leachate quantity but concentrations are low enough that there are no problems with groundwater contamination.

(3) Runoff from spray sites should be avoided. Tiles draining such sites often have direct surface connections through sand lenses which lead to discharge of water with P concentrations over one mg/l during some actual spray events. These peak concentrations are of short duration and drop rapidly as actual irrigation ceases. On a mass balance basis, such high concentrations account for only a small percentage of discharged water and P removal by tiled systems is high (over 80%).

(4) Mature beech-sugar maple forests are not efficient at removal of N from wastewater. Such mature forests should not be used for wastewater renovation.

12.2 MILL CREEK

It would appear that the predominant factor affecting the appearance of pesticide problems in the Great Lakes in the nature of the chemical formulation of the pesticide itself. Persistent compounds such as the chlorinated hydrocarbons are apparently being transported to the lakes despite their lack of use for several years in the watershed. Transport of these compounds are tied closely with the movement of suspended sediments, thus it would seem that measures to control sediment movement would also control the movement of chlorinated hydrocarbons. The problem in the lakes, however, is apparently slowly improving as these compounds reach their ultimate sink in some unavailable compartment of the ecosystem or as they are degraded into more harmless forms. In short, this problem should take care of itself in time assuming no further use of these compounds.

Atrazine and Guthion do appear in Mill Creek but their significance as a problem in the Great Lakes is unclear at this time. Misuse and accidents with pesticides can be expected no matter how strict a particular set of regulations is inforced. The only safeguard under these circumstances is to ban the manufacture and use of formulations that could cause long-term problems in the event of a single accidental introduction.